

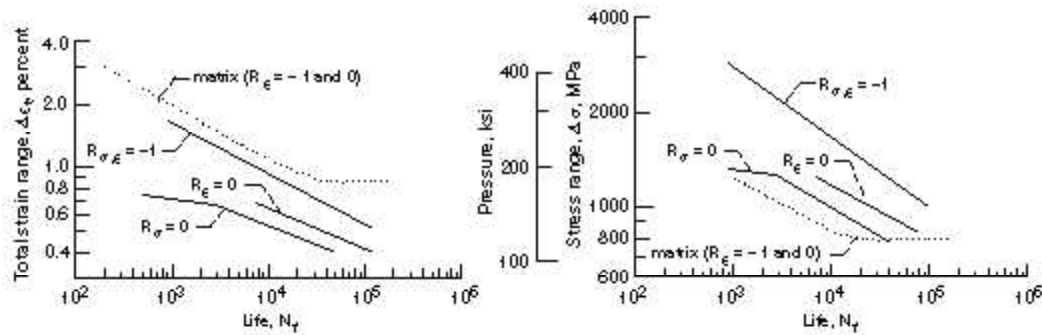
Effects of Control Mode and R-Ratio on the Fatigue Behavior of a Metal Matrix Composite

Because of their high specific stiffness and strength at elevated temperatures, continuously reinforced metal matrix composites (MMC's) are under consideration for a future generation of aeropropulsion systems. Since components in aeropropulsion systems experience substantial cyclic thermal and mechanical loads, the fatigue behavior of MMC's is of great interest.

Almost without exception, previous investigations of the fatigue behavior of MMC's have been conducted in a tension-tension, load-controlled mode. This has been due to the fact that available material is typically less than 2.5-mm thick and, therefore, unable to withstand high compressive loads without buckling. Since one possible use of MMC's is in aircraft skins, this type of testing mode may be appropriate. However, unlike aircraft skins, most engine components are thick. In addition, the transient thermal gradients experienced in an aircraft engine will impose tension-compression loading on engine components, requiring designers to understand how the MMC will behave under fully reversed loading conditions. The increased thickness of the MMC may also affect the fatigue life.

Traditionally, low-cycle fatigue (LCF) tests on MMC's have been performed in load control. For monolithic alloys, low-cycle fatigue tests are more typically performed in strain control. Two reasons justify this choice: (1) the critical volume from which cracks initiate and grow is generally small and elastically constrained by the larger surrounding volume of material, and (2) load-controlled, low-cycle fatigue tests of monolithics invariably lead to unconstrained ratcheting and localized necking--an undesired material response because the failure mechanism is far more severe than, and unrelated to, the fatigue mechanism being studied. It is unknown if this is the proper approach to composite testing. However, there is a lack of strain-controlled data on which to base any decisions. Consequently, this study (ref. 1) addresses the isothermal, LCF behavior of a [0]₂ MMC tested under strain- and load-controlled conditions for both zero-tension and tension-compression loading conditions. These tests were run at 427 °C on thick specimens of SiC-reinforced Ti-15-3.

For the fully-reversed tests, no difference was observed in the lives between the load- and strain-controlled tests. However, for the zero-tension tests, the strain-controlled tests had longer lives by a factor of 3 in comparison to the load-controlled tests. This was due to the fact that under strain-control the specimens cyclically softened, reducing the cracking potential. In contrast, the load-controlled tests ratcheted toward larger tensile strains leading to an eventual overload of the fibers.



Summary of fatigue lives on a strain-range (left) and stress-range (right) basis for the SiC/T-15-3 composite and the unreinforced matrix tested at 427 °C.

Fatigue tests revealed that specimens tested under fully-reversed conditions had lives approximately an order of magnitude longer than for those specimens tested under zero tension. When examined on a strain-range basis, the fully reversed specimens had similar, but still shorter lives than those of the unreinforced matrix material. However, the composite had a strain limitation at short lives because of the limited strain capacity of the brittle ceramic fiber. The composite also suffered at very high lives because of the lack of an apparent fatigue limit in comparison to the unreinforced matrix. The value of adding fibers to the matrix is apparent when the fatigue lives are plotted as a function of stress range. Here, the composite is far superior to the unreinforced matrix because of the additional load-carrying capacity of the fibers.

Reference

1. Lerch, B.; and Halford, G.: Effects of Control Mode and R-Ratio on the Fatigue Behaviour of a Metal Matrix Composite. Proceedings of the TMS/ASM Symposium on Mechanisms and Mechanics of MMC Fatigue, H. Herman, B.S. Majumdar, and B.A. Lerch, eds., Mater. Sci. Eng., vol. A200, nos. 1-2, Sept. 1995, pp. 47-54.